Package: pft (via r-universe)

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Type Package

Title Reference Values and Interpretation for Pulmonary Function Tests

Version 1.0.1

Description Computes predicted values and lower/upper limits of normal for pulmonary function tests according to American Thoracic Society (ATS) and European Respiratory Society (ERS) reference standards. Supports spirometry (Global Lung Function Initiative GLI 2012, Quanjer et al. (2012) <doi:10.1183/09031936.00080312>; and the race-neutral GLI 2022 / GLI Global equations, Bowerman et al. (2023) <doi:10.1164/rccm.202205-0963OC>), static lung volumes (GLI 2021, Hall et al. (2021) <doi:10.1183/13993003.00289-2020>), and the carbon monoxide transfer factor / diffusion capacity (GLI 2017, Stanojevic et al. (2017) <doi:10.1183/13993003.00010-2017>, including the 2020 author correction <doi:10.1183/13993003.50010-2017>). Also assigns interpretive pattern labels (Normal, Non-specific, Obstructed, Restricted, Mixed) from spirometry and lung-volume measurements following the ERS/ATS 2022 interpretation algorithm, Stanojevic et al. (2022) <doi:10.1183/13993003.01499-2021>.

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URL `https://github.com/overdodactyl/pft`

BugReports `https://github.com/overdodactyl/pft/issues`

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Contents

`pft_bdr` *Bronchodilator response per the current ATS/ERS criterion*

Description

Classifies bronchodilator response (BDR) by the percent change in the measured value relative to the patient's predicted value, as recommended by Stanojevic et al. ERJ 2022. Significant BDR is defined as a post-bronchodilator increase of more than 10% of the predicted value in either FEV1 or FVC. This replaces the 2005 standard, which used a >=12% AND >=200 mL change from baseline.

Usage

```
pft_bdr(pre, post, predicted, threshold = BDR_THRESHOLD_PCT_PRED)
```

Arguments

pre, post	Numeric vectors of pre- and post-bronchodilator measurements (same units, same length).
predicted	Numeric vector of predicted (median) values for the same measure, typically the `<measure>_pred` column from a previous call to `pft_spirometry()`.
threshold	Percent-of-predicted change considered significant. Defaults to 10 (the Stanojevic 2022 criterion).

Value

A data frame with one row per input observation and columns:

- `pct_pred_change`: `(post - pre) / predicted * 100`.
- `is_significant`: logical, `TRUE` when `pct_pred_change > threshold`. `NA` is propagated wherever any of `pre`, `post`, `predicted` is `NA`.

Column naming

This function's `pct_pred_change` column is **percent-of-predicted** change (the 2022 criterion). The predecessor `pft_bdr_2005()` emits a similarly-named but different column, `pct_change`, which is **percent-of-baseline** change (`(post - pre) / pre * 100`, the 2005 criterion). The two functions deliberately use distinct column names so a result frame can carry both without ambiguity.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. See the "Bronchodilator responsiveness testing" section.

See Also

`pft_spirometry()` to obtain the predicted FEV1 / FVC values used as the denominator. `pft_interpret()` runs BDR automatically when `<measure>_pre` and `<measure>_post` columns are present.

Examples

```
pft_bdr(pre = 2.5, post = 3.0, predicted = 4.0)
# -> 12.5% of predicted change, is_significant = TRUE
```

pft_bdr_2005 *Bronchodilator response per the Pellegrino 2005 standard*

Description

Classifies bronchodilator response (BDR) by the Pellegrino et al. ERJ 2005 dual criterion: significant if both the relative change from baseline is at least 12% AND the absolute change is at least 200 mL. Replaced in 2022 by `pft_bdr()`'s simpler "> 10% of predicted" rule.

Usage

```
pft_bdr_2005(pre, post)
```

Arguments

`pre, post`	Numeric vectors of pre- and post-bronchodilator measurements, in litres, same length.

Value

A data frame with one row per input observation and three columns: `pct_change` (i.e. `(post - pre) / pre * 100`), `abs_change` (i.e. `post - pre` in litres), and `is_significant` (logical, `TRUE` when `pct_change > 12` AND `abs_change > 0.2`, both inequalities strict per the paper's wording on p. 959: "(>12% of control and >200 mL)"). `NA` propagates wherever either of `pre` / `post` is `NA`.

Column naming

This function's `pct_change` column is **percent-of-baseline** change (the 2005 criterion). The 2022 `pft_bdr()` emits a similarly-named but different column, `pct_pred_change`, which is **percent-of-predicted** change (`(post - pre) / predicted * 100`, the 2022 criterion). The two functions deliberately use distinct column names so a result frame can carry both without ambiguity.

References

Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005;26(5):948-968. doi:10.1183/09031936.05.00035205. Criterion stated in the "Bronchodilator response" section (p. 958) and disambiguated on p. 959.

See Also

`pft_bdr()` for the current Stanojevic 2022 criterion (>10% of predicted). Unlike the 2022 form, the 2005 version does not need the patient's predicted FEV1 / FVC – only the pre and post measurements.

Examples

```
pft_bdr_2005(pre = c(2.5, 2.0), post = c(2.8, 2.1))
# -> first row significant (>=12% AND >=200 mL),
#    second row not (only 5% and 100 mL increase)
```

`pft_change` *Conditional change score for serial PFT measurements*

Description

`pft_change()` computes the conditional change score (CCS) defined in Box 2 of the Stanojevic et al. ERS/ATS 2022 interpretation standard. The CCS evaluates whether the change between two FEV1 z-scores is larger than would be expected from within-subject variability and regression to the mean alone.

Formula (paper Box 2 p. 12):

$$CCS = (z_2 - r \cdot z_1)/\sqrt{1 - r^2}$$

Where the autocorrelation `r` is itself a function of the time interval between measurements and the patient's age at the first time point:

$$r = 0.642 - 0.04 \cdot time(years) + 0.020 \cdot age(years)$$

Changes within `+/- 1.96` change scores are considered within the normal limits per the paper.

This formula was derived from a children/young-people cohort (Stanojevic 2022 references the underlying study and notes the approach has *"yet to be validated, extended to adults"* but permits its use as *"a reasonable tool to facilitate interpretation"*). For adults the 2022 standard alternatively recommends FEV1Q (Box 3); see `pft_fev1q()`.

Usage

```
pft_change(z1, z2, age_t1 = NULL, time_years = NULL, r = NULL)
```

Arguments

`z1, z2`	Numeric vectors of FEV1 z-scores at time 1 and time 2.
`age_t1`	Numeric. Patient age (in years) at the first measurement.
`time_years`	Numeric. Elapsed time between measurements in years (e.g. 0.25 for 3 months, 4 for 4 years).
`r`	Optional. Numeric in `(-1, 1)`. If supplied, used directly in place of the paper's age/time formula – useful for callers who have a population-specific autocorrelation estimate. If `NULL` (the default), `r` is computed from `age_t1` and `time_years` via the Box 2 formula.

Value

A data frame with columns:

- `ccs`: the conditional change score.
- `r_used`: the autocorrelation actually used in the calculation (returned so callers can audit the value chosen).
- `is_significant`: logical, `TRUE` when `|ccs| > 1.96` (i.e. outside the paper's normal-limits range).

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. Box 2 (p. 12).

See Also

`pft_spirometry()` to produce the FEV1 z-scores at each time point.

Examples

```
# Stanojevic 2022 Box 2 worked example: a 14-year-old male whose
# FEV1 z-score dropped from -0.78 to -1.60 over 3 months.
pft_change(z1 = -0.78, z2 = -1.60, age_t1 = 14, time_years = 0.25)
# -> r_used = 0.912, ccs ~= -2.17, is_significant = TRUE

# Same drop spread over 4 years
pft_change(z1 = -0.78, z2 = -1.60, age_t1 = 14, time_years = 4)
# -> r_used = 0.762, ccs ~= -1.55, is_significant = FALSE
```

`pft_classify` *Classify ATS spirometry patterns from spirometry and lung-volume measurements*

Description

`pft_classify()` assigns ATS patterns using spirometry and lung volume data. By default it applies the Stanojevic et al. ERS/ATS 2022 algorithm (Figure 8); pass `standard = "2005"` to apply the predecessor Pellegrino et al. ERJ 2005 algorithm.

Typically called via `pft_interpret()` as part of the one-call workflow; exported for callers who want to apply the classifier to pre-computed columns directly.

Usage

```
pft_classify(
  data,
  standard = c("2022", "2005"),
  year = 2022,
  fev1 = fev1,
  fev1_lln = NULL,
  fvc = fvc,
  fvc_lln = NULL,
  fev1fvc = fev1fvc,
  fev1fvc_lln = NULL,
  tlc = tlc,
  tlc_lln = tlc_lln
)
```

Arguments

`data`
: A data frame containing the six spirometry input columns (`fev1`, `fev1_lln`, `fvc`, `fvc_lln`, `fev1fvc`, `fev1fvc_lln`) and optionally `tlc` and `tlc_lln`. TLC columns are optional – when either is absent from `data`, the classifier routes via the spirometry-only fallback (see "Missing TLC" below).

`standard`
: Which interpretive standard's classifier to apply. `"2022"` (default) follows Stanojevic et al. ERJ 2022 Figure 8 and recognises five labels: `Normal`, `Non-specific`, `Obstructed`, `Restricted`, `Mixed`. `"2005"` follows Pellegrino et al. ERJ 2005 Figure 2 and recognises four labels (`Normal`, `Obstructed`, `Restricted`, `Mixed`). The 2005 algorithm only consults TLC when FVC is below LLN; when FVC is normal it routes directly to `Normal` or `Obstructed` regardless of TLC. This is the dominant source of 2005 -> 2022 reclassification: rows with low TLC but normal FVC (NNNA, ANNA) become `Restricted` under 2022 but stay `Normal` under 2005; rows with low FEV1/FVC and low TLC but normal FVC (NNAA, ANAA) become `Mixed` under 2022 but stay `Obstructed` under 2005; the isolated-low-FVC cells (NANN, AANN) become `Non-specific` under 2022 but `Normal` under 2005.

`year`
: GLI year suffix to use when looking up the spirometry LLN columns (`fev1_lln`, `fvc_lln`, `fev1fvc_lln`). Defaults to `2022` (GLI Global, race-neutral). Set to match the `year` argument used in the upstream `pft_spirometry()` / `pft_interpret()` call. The TLC columns (volumes reference) are unsuffixed and are not affected by `year`.

`fev1, fev1_lln, fvc, fvc_lln, fev1fvc, fev1fvc_lln, tlc, tlc_lln`
: Column references for the eight inputs. Defaults are the canonical names (`fev1`, `fev1_lln`, ...); override with a bare name, a string, or `!!var` (see "Column-name overrides" below).

Value

The original data frame with two appended columns:

- `ats_classification`: pattern label. Values depend on the selected `standard`; see above.

- `ats_pattern_combination`: a 4-character string in fixed column order **FEV1, FVC, FEV1/FVC, TLC**, with `"A"` denoting the value is below its LLN, `"N"` denoting it is at or above, and `"?"` denoting the value (and its LLN) was missing. So `"NNAN"` means only FEV1/FVC is below its LLN (pure airway obstruction); `"AANA"` means FEV1, FVC, and TLC are all low while FEV1/FVC is preserved (restriction); `"NNA?"` means FEV1/FVC is below LLN and TLC is unknown. The pattern-combination string is independent of the `standard` selected.

Column-name overrides

Each column-reference argument accepts three forms:

- a **bare column name** – `fev1 = my_fev1`
- a **string** – `fev1 = "my_fev1"`
- an **injected value** – `fev1 = !!my_var` where `my_var <- "my_fev1"`

Defaults are the canonical pft column names, so callers whose data already follows the convention pass no extra arguments. The two TLC references (`tlc`, `tlc_lln`) are optional: when either resolves to a column not present in `data`, the spirometry-only fallback triggers without raising an error.

Missing TLC (spirometry-only fallback)

When the three spirometry inputs (`fev1`, `fvc`, `fev1fvc`) and their LLNs are all present but TLC is missing, `pft_classify()` falls back to a spirometry-only branch instead of returning `NA`. Under both standards, an `"Obstructed"` row is still recognisable from FEV1/FVC < LLN alone (Mixed would require TLC to distinguish but Mixed is itself an obstructive defect, so the row is labelled `"Obstructed"`). Under the 2005 standard, rows with FVC $\geq$ LLN classify deterministically because the 2005 flowchart does not consult TLC in that branch (so `"Normal"` is emitted for normal spirometry). Cells where TLC would have been the disambiguating input (Normal vs Restricted, Non-specific vs Restricted under 2022; Normal vs Restricted, Obstructed vs Mixed under 2005) remain `NA`. Rows where any spirometry input is itself missing always return `NA`. See `pft_prism()` for the spirometry-only PRISm screen which is reported as a separate logical column.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. The 2022 classifier follows the spirometry interpretation flowchart in Figure 8 and the pattern definitions in Tables 5 and 8.

Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005;26(5):948-968. doi:10.1183/09031936.05.00035205. The 2005 classifier follows Figure 2.

See Also

`pft_prism()` for the spirometry-only PRISm screen (no TLC required). `pft_severity()` / `pft_severity_2005()` grade per-measure severity. `pft_interpret()` runs the classifier as part of the one-call workflow and also accepts the `standard` argument for end-to-end reclassification.

Examples

```
data <- data.frame(fev1 = c(3.453, 2.385),
                             fev1_lln_2022 = c(3.303, 3.384),
                             fvc = c(4.733, 3.485),
                             fvc_lln_2022 = c(4.214, 4.24),
                             fev1fvc = c(0.600, 0.827),
                             fev1fvc_lln_2022 = c(0.681, 0.700),
                             tlc = c(1.5, 2.3),
                             tlc_lln = c(2, 2.5))
          pft_classify(data)
          pft_classify(data, standard = "2005")

          # Column-name override: data using non-canonical names.
          alt <- data.frame(my_fev1 = 3.0, my_fev1_lln = 2.5,
                            fvc = 4.0, fvc_lln_2022 = 3.5,
                            fev1fvc = 0.65, fev1fvc_lln_2022 = 0.70,
                            tlc = 6.0, tlc_lln = 5.0)
          pft_classify(alt, fev1 = my_fev1, fev1_lln = my_fev1_lln)
```

---

pft_diffusion — *Compute carbon monoxide diffusion capacity or transfer factor reference values for given demographics*

Description

`pft_diffusion()` computes ATS-compliant upper and lower normal limits for carbon monoxide measured diffusion capacity and European equivalents including DLCO (or TLCO), KCO, and VA.

Usage

```
pft_diffusion(data, SI.units = FALSE, sex = sex, age = age, height = height)
```

Arguments

`data`	A data frame containing columns for sex ("M","F"), age (in years, in the range 5-90 per the GLI 2017 spline tables) and height (in centimeters). If `data` also contains a `<measure>_measured` column for any of the active measures (`tlco`, `kco_si`, `va` under SI units; `dlco`, `kco_tr`, `va` under traditional), the measured value is used to compute z-score and percent-predicted (see Value).
`SI.units`	A boolean. Returns the reference values in SI units if TRUE . and Traditional units if FALSE.
`sex, age, height`	Column references. By default `pft_diffusion()` reads from `sex`, `age`, and `height`. Override via a bare name (`sex = Sex`), a string (`sex = "Sex"`), or an rlang injection (`sex = !!my_var`). The user's original column names are preserved in the output.

Value

The original data frame with extra columns appended for each measure:

- `<measure>_pred`: predicted (median) value.
- `<measure>_lln`: lower limit of normal (5th percentile).
- `<measure>_uln`: upper limit of normal (95th percentile). If a `<measure>_measured` column was supplied in `data`, two additional columns are emitted:
- `<measure>_zscore`: LMS z-score `((measured/M)^L - 1) / (L*S)`.
- `<measure>_pctpred`: percent predicted `(measured / pred) * 100`.

References

Stanojevic S, Graham BL, Cooper BG, et al. Official ERS technical standards: Global Lung Function Initiative reference values for the carbon monoxide transfer factor for Caucasians. Eur Respir J. 2017;50(3):1700010. doi:10.1183/13993003.000102017. (Author correction: doi:10.1183/13993003.50010-2017, applied here.)

See Also

`pft_spirometry()` and `pft_volumes()` for the analogous reference-value functions. `pft_severity()` grades DLCO impairment severity from the z-score column produced here. `pft_interpret()` composes all three reference functions in one call.

Examples

```
data <- data.frame(sex=c("M","F"),
                   age=c(30,5.1),
                   height=c(178,50))
pft_diffusion(data)
```

`pft_diffusion_interpret` *Classify a diffusion result into a clinical pattern category*

Description

Takes per-patient `dlco_zscore`, `va_zscore`, and `kco_zscore` columns (the outputs of `pft_diffusion()` when `_measured` columns are supplied) and assigns a clinical interpretive category per the Hughes & Pride 2012 framework adopted by the ERS/ATS Stanojevic 2017 task force.

Usage

```
pft_diffusion_interpret(
  data,
  SI.units = FALSE,
  dlco = NULL,
```

```
  va = NULL,
  kco = NULL
)
```

Arguments

data	A data frame containing the three z-score input columns.
SI.units	Logical, default `FALSE`. Selects the default column names for `dlco` and `kco`. Traditional units (`FALSE`): `dlco_zscore` and `kco_tr_zscore`. SI units (`TRUE`): `tlco_zscore` and `kco_si_zscore`. `va` defaults to `va_zscore` in both unit systems.
dlco, va, kco	Column references for the three z-score inputs. `dlco` and `kco` default to `NULL`, which means: pick the canonical column name based on `SI.units`. Pass a bare name, a string, or `!!var` to override (see "Column-name overrides").

Details

The classifier consumes z-scores only and is unit-agnostic, but the default input column names differ between unit systems. Set `SI.units = TRUE` to pick up the SI-units column set (`tlco_zscore`, `va_zscore`, `kco_si_zscore`); otherwise the traditional-units column set (`dlco_zscore`, `va_zscore`, `kco_tr_zscore`) is used. Override individual column names via the `dlco` / `va` / `kco` arguments.

Typically called via `pft_interpret()` as part of the one-call workflow; exported for callers who want to apply the classifier to pre-computed z-score columns directly.

Value

The original data frame with a single appended column: `diffusion_category`. Possible values:

`"Normal"` All three z-scores above LLN.

`"Parenchymal"` Low DLCO, low KCO, normal VA.

`"Volume loss"` Low DLCO, low VA, normal or elevated KCO.

`"Mixed"` Low DLCO, low VA, low KCO.

`"Vascular (suggested)"` Low DLCO, normal VA, low or elevated KCO.

`"Elevated KCO"` Normal DLCO with elevated KCO ($z > +1.645$).

`"Other"` Combination not matching any of the above patterns (e.g., low VA in isolation).

`NA` Required z-score columns missing.

The category labels describe the z-score pattern only; differential diagnosis is left to the clinician (see the Hughes & Pride 2012 source paper for clinical interpretation).

Column-name overrides

Each column-reference argument accepts three forms:

- a **bare column name** – `dlco = my_dlco`
- a **string** – `dlco = "my_dlco"`

- an **injected value** – `dlco = !!my_var` where `my_var <- "my_dlco"`

`dlco` and `kco` default to `NULL`, which selects the canonical name based on `SI.units` (traditional or SI). Passing an explicit reference overrides this selection.

References

Hughes JM, Pride NB. Examination of the carbon monoxide diffusing capacity (DL(CO)) in relation to its KCO and VA components. *Am J Respir Crit Care Med*. 2012;186(2):132-139. doi:10.1164/rccm.2011122160CI.

Stanojevic S, Graham BL, Cooper BG, et al. ERS/ATS technical standard: Global Lung Function Initiative reference values for the carbon monoxide transfer factor for Caucasians. *Eur Respir J*. 2017;50:1700010. doi:10.1183/13993003.000102017. (Provides the z-score reference standard whose LLN at z = -1.645 is used here. The clinical interpretation framework is from Hughes & Pride 2012, adopted by the 2017 task force.)

See Also

`pft_diffusion()` to compute the input z-scores; `pft_interpret()` for the one-call workflow that auto-runs this classifier when diffusion outputs are present.

Examples

```
# Three patients: normal, parenchymal (low DLCO/KCO, normal VA),
# and volume loss (low DLCO/VA, normal KCO).
d <- data.frame(
  dlco_zscore  = c(-0.5, -2.0, -2.0),
  va_zscore    = c(-0.5, -0.5, -2.0),
  kco_tr_zscore = c(-0.5, -2.0, -0.5)
)
pft_diffusion_interpret(d)

# SI units (TLCO / KCO_SI). Pass SI.units = TRUE.
d_si <- data.frame(
  tlco_zscore   = c(-0.5, -2.0),
  va_zscore     = c(-0.5, -0.5),
  kco_si_zscore = c(-0.5, -2.0)
)
pft_diffusion_interpret(d_si, SI.units = TRUE)
```

`pft_dlco_hb_correct` *Adjust a measured DLCO / TLCO for the patient's hemoglobin*

Description

Applies the Cotes 1972 hemoglobin correction to a measured carbon monoxide transfer factor (DLCO or TLCO), returning the value that would have been measured if the patient's hemoglobin equaled the age- and sex-specific reference. The correction is intended for clinical interpretation: after applying it, the corrected DLCO can be passed to `pft_diffusion()` (whose reference equations assume the reference Hb).

Usage

```
pft_dlco_hb_correct(dlco, hemoglobin, sex, age = NA_real_)
```

Arguments

`dlco`	Numeric vector of measured DLCO or TLCO values, any unit system (the correction is multiplicative and unit-agnostic).
`hemoglobin`	Numeric vector of measured hemoglobin in g/L (routine clinical adult range 120-160 g/L). Pass g/L directly; the function does not detect or convert g/dL inputs.
`sex`	Character vector ("M"/"F"). Soft-corrected via the internal `normalize_sex_vec()` helper so "Male", "female", etc. work.
`age`	Optional numeric vector. When supplied, males aged < 15 yr use the female / child reference (134 g/L) per Stanojevic 2017 p. 11. When omitted (the default `NA_real_`), males default to the adult reference (146).

Details

Stanojevic et al. ERJ 2017 explicitly recommends (Table 4 p. 9) that the published GLI TLCO reference values be **uncorrected** for Hb, with Hb levels considered separately during interpretation. This function provides that interpretive step.

Formula (Cotes 1972; reformulated from Stanojevic 2017 p. 9, with constants 1.7 and 0.7 reflecting the membrane / capillary diffusing capacity ratio of 0.7 mL min^-1 mmHg^-1 mL-blood^-1):

$$TLCO_{Hb} = TLCO_{measured} \times \frac{1.7 \cdot Hb_{ref}}{Hb + 0.7 \cdot Hb_{ref}}$$

Reference Hb levels (Stanojevic 2017 p. 11):

- Males aged >= 15 yr: 146 g/L
- Females (any age) and children < 15 yr: 134 g/L

When `hemoglobin` == `Hb_ref` the correction factor is exactly 1 (no adjustment). Anaemic patients (`hemoglobin` < `Hb_ref`) receive an UPWARD correction reflecting that less Hb means less CO uptake and a depressed measured value.

Value

Numeric vector of Hb-corrected DLCO / TLCO values, same units as `dlco`. `NA` propagates from any input.

References

Stanojevic S, Graham BL, Cooper BG, et al. Official ERS technical standards: Global Lung Function Initiative reference values for the carbon monoxide transfer factor for Caucasians. Eur Respir J. 2017;50(3):1700010. doi:10.1183/13993003.000102017. Hb correction is discussed on p. 9 and the Cotes formula context on p. 11.

Cotes JE, Dabbs JM, Elwood PC, et al. Iron-deficiency anaemia: its effect on transfer factor for the lung (diffusing capacity) and ventilation and cardiac frequency during sub-maximal exercise. Clin Sci. 1972;42:325-335.

See Also

`pft_diffusion()` for the reference-value computation that consumes the Hb-corrected DLCO.

Examples

```
# An anaemic adult male (Hb = 100 g/L vs reference 146 g/L) with
# measured DLCO of 20 mL/min/mmHg has a Hb-adjusted DLCO of
# 20 x (1.7 x 146) / (100 + 0.7 x 146) ~= 24.55.
pft_dlco_hb_correct(dlco = 20, hemoglobin = 100,
                    sex = "M", age = 40)

# No-op when Hb equals reference.
pft_dlco_hb_correct(20, hemoglobin = 146, sex = "M")

# Children use the female / child reference (134 g/L) regardless
# of sex.
pft_dlco_hb_correct(20, hemoglobin = 134, sex = "M", age = 10)
```

`pft_example` *Synthetic example PFT cohort*

Description

A small synthetic cohort of 20 patients spanning the clinical patterns the package classifies (Normal, Obstructed, Restricted, Mixed, Non-specific, PRISm) plus a few bronchodilator-response cases. Demographics are random within plausible ranges; measured values were hand-picked so that each row lands in its target pattern after the GLI reference equations are applied.

Usage

```
pft_example
```

Format

A tibble with 20 rows and 11 columns:

patient_id Integer 1-20. Synthetic identifier.

sex Character: `"M"` or `"F"`.

age Numeric, years.

height Numeric, centimetres.

race One of `"Caucasian"`, `"AfrAm"`, `"NEAsia"`, `"SEAsia"`.

fev1_measured Measured FEV1 in litres. May be `NA`.

fvc_measured Measured FVC in litres.

fev1fvc_measured Measured FEV1/FVC ratio.

tlc_measured Measured TLC in litres. May be `NA` for rows intended to demonstrate spirometry-only workflows.

fev1_pre Pre-bronchodilator FEV1 in litres. `NA` when not a BDR scenario.

fev1_post Post-bronchodilator FEV1 in litres. `NA` when not a BDR scenario.

Details

No real patient data. Generated by `data-raw/build_pft_example.R`. Provided for examples, vignettes, and quick experimentation.

Source

`data-raw/build_pft_example.R` (synthetic; no real patient data).

Examples

```
data(pft_example)
head(pft_example)
pft_interpret(pft_example)
```

---

pft_fev1q *FEV1Q: ratio of FEV1 to a sex-specific survivable lower limit*

Description

Computes the FEV1Q survival index proposed by Miller & Pedersen (ERJ 2010) and discussed as an adult alternative to the conditional change score in Box 3 (p. 13) of the Stanojevic et al. ERJ 2022 interpretation standard. FEV1Q expresses FEV1 in relation to a "bottom line" required for survival, rather than how far an individual's result is from their predicted value; the race-neutral evidence base was consolidated by Balasubramanian et al. (ERJ 2024).

Usage

```
pft_fev1q(fev1, sex, age = NA_real_)
```

Arguments

- `fev1` Numeric vector of FEV1 measurements in litres.
- `sex` Character vector of patient sex. Accepts the soft- correctable variants from `pft_spirometry()` ("Male", "female", etc.); unrecognized values yield `NA`.
- `age` Optional numeric vector. When supplied, rows with `age < 18` return `NA_real_` per the paper's "not appropriate for children and adolescents" caveat. Default `NA_real_` skips the guard.

Details

Formula (Box 3 verbatim):

$$FEV1Q = FEV1/Q_{sex}$$

where $Q_{male} = 0.5L$ and $Q_{female} = 0.4L$ are the sex-specific 1st percentiles of the FEV1 distribution in adult lung-disease populations. The index approximates the number of turnovers remaining of a lower survivable limit of FEV1; values closer to 1 indicate greater risk of death.

The 2022 standard cautions (running text on p. 13, immediately preceding Box 3): "FEV1Q is not appropriate for children and adolescents." When `age` is supplied, rows with `age < 18` return `NA_real_`. When `age` is omitted, the age guard is skipped and the caller is responsible for restricting input to adults.

For longitudinal interpretation in adults the 2022 standard suggests FEV1Q as an alternative to the conditional change score (see `pft_change()`): under normal circumstances 1 unit of FEV1Q is lost approximately every 18 years (every ~10 years in smokers and the elderly).

Value

Numeric vector of FEV1Q ratios, same length as `fev1`. `NA` propagates from any input.

References

Miller MR, Pedersen OF. New concepts for expressing forced expiratory volume in 1 s arising from survival analysis. Eur Respir J. 2010;35(4):873-882. doi:10.1183/09031936.00025809. Original proposal of the FEV1Q index and the sex-specific 1st-percentile denominators (0.5 L male, 0.4 L female).

Balasubramanian A, Wise RA, Stanojevic S, Miller MR, McCormack MC. FEV1Q: a race-neutral approach to assessing lung function. Eur Respir J. 2024;63(4):2301622. doi:10.1183/13993003.01622-2023. Race-neutral validation of the FEV1Q index.

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. Discusses FEV1Q in Box 3 (p. 13) as an adult alternative to the conditional change score.

See Also

`pft_change()` for the conditional change score (the children / young-people sibling); `pft_severity()` for the z-score-based severity grading.

Examples

```
# Stanojevic 2022 Box 3 worked example: a 70-year-old woman with
# FEV1 of 0.9 L has FEV1Q of 0.9 / 0.4 = 2.25.
pft_fev1q(0.9, "F", age = 70)

# Vectorised across sex.
pft_fev1q(c(1.0, 1.0), c("M", "F"))

# Adolescents return NA when age is supplied.
pft_fev1q(1.0, "F", age = 10)
```

`pft_gold` *Grade COPD severity by GOLD criteria*

Description

Returns the GOLD spirometric severity grade (1-4) for one or more patients given their FEV1 expressed as a percent of predicted, optionally enforcing the GOLD-mandated prerequisite of confirmed airflow obstruction (FEV1/FVC < 0.7).

Usage

```
pft_gold(fev1_pctpred, fev1fvc = NA_real_)
```

Arguments

`fev1_pctpred` Numeric vector of FEV1 % predicted values (e.g. the `fev1_pctpred` column from `pft_spirometry()` when measured values are supplied).

`fev1fvc` Optional numeric vector of post-bronchodilator FEV1/FVC ratios (e.g. the `fev1fvc_measured` column). When supplied, rows with `fev1fvc >= 0.7` are returned as `NA_character_` – per GOLD 2026 Figure 2.10, the grading applies only "In patients with COPD (FEV1/FVC < 0.7)". When omitted (the default `NA_real_`) or all-NA, no prerequisite check is performed and a grade is returned for every non-NA `fev1_pctpred`.

Details

GOLD severity grades for airflow obstruction (Figure 2.10 of the GOLD 2026 report, content page 38):

Grade	Severity	FEV1 % predicted
GOLD 1	Mild	`>= 80`
GOLD 2	Moderate	`>= 50 and < 80`
GOLD 3	Severe	`>= 30 and < 50`
GOLD 4	Very severe	`< 30`

GOLD specifies the prerequisite "In patients with COPD (FEV1/FVC < 0.7)" explicitly above Figure 2.10's grade table; the surrounding text (content p. 37) repeats this requirement. Supplying `fev1fvc` enforces the GOLD fixed-cutoff prerequisite. Callers wanting an LLN-based prerequisite instead should use `pft_classify()` to identify obstructed patients and mask `pft_gold()` output by hand.

Value

Character vector with values "GOLD 1", "GOLD 2", "GOLD 3", "GOLD 4", or NA. NA is returned for rows with missing `fev1_pctpred` OR (when `fev1fvc` is supplied) rows that fail the airflow-obstruction prerequisite.

References

Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global Strategy for the Diagnosis, Management and Prevention of Chronic Obstructive Pulmonary Disease, 2026 Report. Figure 2.10. https://goldcopd.org.

See Also

`pft_classify()` for LLN-based airflow obstruction identification (Stanojevic 2022); `pft_severity()` for the z-score-based severity scheme (which differs from GOLD's percent-predicted scheme).

Examples

```
# Without prerequisite check (backward-compatible): one grade per
# non-NA input.
pft_gold(c(85, 65, 40, 25))
# -> "GOLD 1" "GOLD 2" "GOLD 3" "GOLD 4"

# With prerequisite check: the third patient has FEV1/FVC = 0.75
# (no airflow obstruction) and is returned NA.
pft_gold(c(85, 65, 40, 25), fev1fvc = c(0.65, 0.60, 0.75, 0.55))
# -> "GOLD 1" "GOLD 2" NA "GOLD 4"
```

---

pft_interpret *Comprehensive ATS/ERS PFT interpretation in one call*

Description

`pft_interpret()` is a single-call workflow that combines every interpretation primitive in this package into a complete clinical report per the Stanojevic et al. ERJ 2022 standard. It auto-detects which computations are possible from the input columns and skips anything it cannot do:

- If sex / age / height (and race, for `year = 2012`) are present, it computes spirometry reference values via `pft_spirometry()`.
- If sex / age / height are present, it computes lung-volume reference values via `pft_volumes()`.

- If sex / age / height are present, it computes diffusion reference values via pft_diffusion().
- For each measure whose _measured column is present, z-score and percent-predicted are appended (see the individual reference functions for details).
- For each measure with a z-score, a <measure>_severity column is appended via pft_severity().
- If fev1_measured, fvc_measured, fev1fvc_measured, and tlc_measured columns are present, the ATS pattern classifier (pft_classify()) labels each row.
- If tlc_measured, rv_tlc_measured, and fev1fvc_measured are present (with their LLNs / ULNs computable), the lung- volume sub-pattern classifier (pft_volume_subpattern()) adds a volume_subpattern column. When frc_tlc_measured / frc_tlc_uln are also present, both volume ratios are consulted per Stanojevic 2022 Figure 10.
- If fev1_measured, fev1fvc_measured, and their LLNs are resolvable, pft_prism() adds a prism flag (independent of TLC).
- If <measure>_pre and <measure>_post columns are present for any spirometry measure, pft_bdr() adds <measure>_bdr_pct and <measure>_bdr_significant columns.

This is the recommended entry point for clinical-style reporting; the individual reference and interpretation functions are exported for callers who need finer-grained control.

Usage

```
pft_interpret(
  data,
  year = 2022,
  SI.units = FALSE,
  standard = c("2022", "2005"),
  sex = sex,
  age = age,
  height = height,
  race = race
)
```

Arguments

data	A data frame containing whatever inputs are available. See Details for the column-name conventions.
year	GLI spirometry equation year. Defaults to 2022 (GLI Global, race-neutral). See pft_spirometry().
SI.units	Whether to report diffusion in SI units. See pft_diffusion().
standard	Interpretive standard whose downstream rules to apply: "2022" (default) uses Stanojevic et al. ERJ 2022 for pattern classification, severity grading, and BDR; "2005" uses the Pellegrino et al. ERJ 2005 predecessor. The selected standard does *not* affect the GLI reference equations (those are controlled by year) – only the downstream interpretive logic. Useful for reclassification analyses comparing the two standards on the same cohort.

`sex, age, height, race`
: Column references. By default `pft_interpret()` reads from `sex`, `age`, `height`, and (for `year = 2012`) `race`. Override via a bare name (`sex = Sex`), a string (`sex = "Sex"`), or an rlang injection (`sex = !!my_var`). The `_measured`, `_pre`, and `_post` columns are still auto-detected by name and not overridable.

Details

To trigger z-scores and percent-predicted on a measure, include the corresponding `<measure>_measured` column in `data` (e.g. `fev1_measured`, `frc_measured`, `dlco_measured`). To trigger BDR, include `<measure>_pre` and `<measure>_post` columns for any of FEV1, FVC, FEV1/FVC.

All outputs trace to a specific equation, table, or figure in Stanojevic et al. ERJ 2022 or the underlying GLI reference papers; see the `@references` blocks on the individual functions.

Value

The original data frame with every applicable reference value, z-score, percent predicted, severity grade, pattern label, PRISm flag, and BDR result appended.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021.

Examples

```
patient <- data.frame(
  sex = "M", age = 45, height = 178, race = "Caucasian",
  fev1_measured = 2.5, fvc_measured = 3.8, fev1fvc_measured = 2.5/3.8,
  tlc_measured  = 6.0
)
pft_interpret(patient)
```

`pft_long` *Pivot a* `pft_result` *to long form*

Description

Reshapes a wide `pft_interpret()` / `pft_spirometry()` / `pft_volumes()` / `pft_diffusion()` output (one row per patient, one column per measure × statistic) into long form (one row per `(patient, measure, year)` with columns for each statistic). This is the natural shape for `dplyr` / `ggplot2` faceting, cohort modelling, and `broom`-style downstream workflows.

Usage

```
pft_long(x, ...)
```

Arguments

x — A data frame; typically a `pft_result` but any data frame with `<measure>_pred[_<year>]` columns works. Named `x` (rather than `data`) to match the S3 first-argument convention shared with `print.pft_result`, `plot.pft_result`, and the other `pft_result` methods.

... — Currently unused; reserved for forward compatibility.

Details

Discovery is keyed off `<measure>_pred` columns; the four-digit GLI year is extracted from the column suffix and recorded in the `year` column. Spirometry outputs from `pft_spirometry()` / `pft_interpret()` always carry a year suffix (`fev1_pred_2012`, `fev1_pred_2022`, ...) and produce a populated `year`; lung-volume (Hall 2021) and diffusion (GLI 2017) outputs are unsuffixed and produce `year` = `NA` until a competing standard ships and the same suffixing convention is adopted there. Columns whose suffix does not match a recognised statistic are ignored, so id / demographic columns are dropped (use the `.patient` integer to join back).

Value

A tibble with columns `.patient` (integer row position), `measure`, `year` (character; `NA` for non-suffixed outputs), `pred`, `lln`, `uln`, `measured`, `zscore`, `pctpred`, and `severity`. Missing statistics fill with `NA` of the appropriate type.

See Also

`pft_interpret()` to produce the wide-form input.

Examples

```
patient <- data.frame(
  sex = c("M","F"), age = c(45, 60), height = c(178, 165),
  race = "Caucasian",
  fev1_measured = c(2.5, 1.8), fvc_measured = c(3.8, 2.4)
)
result <- pft_interpret(patient)
pft_long(result)
```

`pft_plot` — *Clinical visualisation for a single PFT result*

Description

`pft_plot()` draws a single-patient z-score figure: one row per measure, points at the patient's z-score, shaded reference bands for the four Stanojevic 2022 severity grades returned by `pft_severity()`: normal (z >= -1.645), mild (-2.5 <= z < -1.645), moderate (-4 <= z < -2.5), and severe (z < -4). The normal band extends symmetrically above zero to the upper limit of normal; values above the ULN are shown but are not a 2022 severity grade.

Requires the `ggplot2` package (a Suggested dependency).

Usage

```
pft_plot(data)
```

Arguments

data	A single-row data frame produced by pft_interpret(), pft_spirometry(), pft_volumes(), or pft_diffusion() with measured values supplied (i.e. at least one <measure>_zscore column present). Errors if nrow(data) != 1.

Value

A ggplot object.

See Also

pft_interpret() for the input data shape.

Examples

```
patient <- data.frame(
  sex = "M", age = 45, height = 178, race = "Caucasian",
  fev1_measured    = 2.5,
  fvc_measured     = 3.8,
  fev1fvc_measured = 2.5 / 3.8,
  tlc_measured     = 6.0
)
pft_plot(pft_interpret(patient))
```

---

pft_prism *Screen for Preserved Ratio Impaired Spirometry (PRISm)*

Description

PRISm is the spirometry-only manifestation of the "non-specific" pattern when TLC is not available: a low FEV1, a low FVC, and a preserved (normal) FEV1/FVC ratio. The 2022 ERS/ATS interpretation standard (Stanojevic et al.) classifies it in Table 5 with row "Non-specific pattern" (FEV1 reduced, FVC reduced, FEV1/FVC normal).

Typically called via pft_interpret() as part of the one-call workflow; exported for callers who want to apply the screen to pre-computed columns directly.

This function adds a prism logical column to the data frame. PRISm is a spirometry-only screen and does not require a TLC measurement.

Usage

```
pft_prism(
  data,
  year = 2022,
  fev1 = fev1,
  fev1_lln = NULL,
  fvc = fvc,
  fvc_lln = NULL,
  fev1fvc = fev1fvc,
  fev1fvc_lln = NULL
)
```

Arguments

`data`	A data frame containing the six input columns named below.
`year`	GLI year suffix used when looking up the LLN columns (`fev1_lln`, `fvc_lln`, `fev1fvc_lln`). Defaults to `2022`. Set to match the `year` argument used in the upstream `pft_spirometry()` / `pft_interpret()` call.
`fev1, fev1_lln, fvc, fvc_lln, fev1fvc, fev1fvc_lln`	Column references for the six required columns. Defaults are the canonical names (`fev1`, `fev1_lln_<year>`, ...); override with a bare name, a string, or `!!var` (see "Column-name overrides" below).

Value

The original data frame with a `prism` logical column appended. `NA` propagates from any of the six input columns.

Column-name overrides

Each column-reference argument accepts three forms:

- a **bare column name** – `fev1 = my_fev1`
- a **string** – `fev1 = "my_fev1"`
- an **injected value** – `fev1 = !!my_var` where `my_var <- "my_fev1"`

Defaults are the canonical pft column names, so callers whose data already follows the convention pass no extra arguments.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. PRISm appears in Table 5 as the spirometry-only form of the non-specific pattern.

See Also

`pft_classify()` for the full ATS pattern classification when TLC is available; `pft_interpret()` runs both PRISm and full classification automatically when the relevant columns are present.

Examples

```
d <- data.frame(fev1    = 2.0, fev1_lln_2022    = 2.5,
                fvc     = 2.6, fvc_lln_2022     = 3.0,
                fev1fvc = 0.80, fev1fvc_lln_2022 = 0.70)
pft_prism(d)

# Column-name override: data using non-canonical names.
d2 <- data.frame(my_fev1 = 2.0, my_fev1_lln = 2.5,
                 fvc = 2.6, fvc_lln_2022 = 3.0,
                 fev1fvc = 0.80, fev1fvc_lln_2022 = 0.70)
pft_prism(d2, fev1 = my_fev1, fev1_lln = my_fev1_lln)
```

---

pft_quality *Grade spirometry quality per ATS/ERS 2019*

Description

Assigns one of grades A-F to a set of acceptable spirometry maneuvers for a single measure (FEV1 or FVC) per the Graham et al. ATS/ERS 2019 technical standard, Table 10. Grades depend on the number of acceptable maneuvers and the difference between the best two values.

Usage

```
pft_quality(values, age = NA_real_)
```

Arguments

`values`	Numeric vector of measurements (litres) from each acceptable maneuver for ONE patient and ONE measure. Length 0 is allowed and yields grade `"F"`.
`age`	Patient age, in years. The repeatability thresholds tighten for children aged 6 or younger; the threshold is the *greater* of the absolute child value (0.100 / 0.150 / 0.200 L for A / C / D) and 10% of the highest measured value, per Table 10's footnote. Defaults to `NA_real_`, which uses the adult thresholds.

Details

Grade definitions (Table 10, paper p. e83). Adult thresholds in parentheses; child (age <= 6) thresholds are `max(absolute, 0.10 · max(values))`:

- **A**: >= 3 acceptable maneuvers; best two within 0.150 L (0.100 L for child).
- **B**: 2 acceptable maneuvers; best two within 0.150 L (0.100 L for child).
- **C**: >= 2 acceptable maneuvers; best two within 0.200 L (0.150 L for child).
- **D**: >= 2 acceptable maneuvers; best two within 0.250 L (0.200 L for child).
- **E**: >= 2 acceptable maneuvers with best-two diff exceeding the D threshold, OR exactly 1 acceptable maneuver.

- **F**: 0 acceptable maneuvers.

Grade **U** ("0 acceptable AND >= 1 usable") from Table 10 is NOT currently distinguished from F. Implementing U would require extending the API to take a separate vector of usable-but-not-acceptable maneuvers; with zero acceptable values, the function returns F unconditionally.

Value

A length-1 character with value `"A"`, `"B"`, `"C"`, `"D"`, `"E"`, or `"F"`.

References

Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med. 2019;200(8):e70-e88. doi:10.1164/rccm.2019081590ST.

See Also

`pft_interpret()` for the downstream interpretation once acceptable maneuvers have been selected.

Examples

```
pft_quality(c(3.20, 3.12, 3.10))          # Grade A (n>=3 within 0.150)
pft_quality(c(3.20, 3.12))                # Grade B (n=2 within 0.150)
pft_quality(c(3.20, 3.02))                # Grade C (n>=2 within 0.200)
pft_quality(c(3.20, 2.97))                # Grade D (n>=2 within 0.250)
pft_quality(c(3.20, 2.80))                # Grade E (n>=2 diff > 0.250)
pft_quality(c(3.20))                      # Grade E (only 1)
pft_quality(numeric(0))                   # Grade F (none)
```

`pft_severity` *Grade severity of lung function impairment from a z-score*

Description

Assigns one of four severity categories (`"normal"`, `"mild"`, `"moderate"`, `"severe"`) to a z-score per the Stanojevic et al. ERS/ATS 2022 interpretation standard. The same grading applies uniformly to spirometry, lung-volume, and diffusion measures.

Boundary conventions (matching the function's implementation):

Grade	z-score
normal	`z >= -1.645`
mild	`-2.5 <= z < -1.645`
moderate	`-4 <= z < -2.5`
severe	`z < -4`

Usage

```
pft_severity(zscore)
```

Arguments

`zscore`	Numeric vector of z-scores.

Value

Character vector the same length as `zscore` with values `"normal"`, `"mild"`, `"moderate"`, `"severe"`, or `NA`.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. The cut points are taken from the "Severity of lung function impairment" section.

See Also

`pft_classify()` for the pattern label that severity sits alongside; `pft_gold()` for COPD-specific severity from FEV1 percent predicted; `pft_interpret()` applies this grading to every z-score column in one call.

Examples

```
pft_severity(c(0, -1.7, -3, -5))
# -> "normal" "mild" "moderate" "severe"
```

`pft_severity_2005` *Severity grading per the Pellegrino 2005 standard*

Description

Assigns a five-band severity grade from FEV1 percent predicted, per the Pellegrino et al. ERJ 2005 standard (the predecessor to the 2022 z-score-based grading implemented by `pft_severity()`).

Boundary conventions (matching the function's implementation):

Grade	FEV1 % predicted
mild	`>= 70%`
moderate	`60% - 69%`
moderately severe	`50% - 59%`
severe	`35% - 49%`
very severe	`< 35%`

Note that unlike `pft_severity()`, the 2005 grading has no "normal" tier – the grades describe the severity of an *impairment* that has already been identified, and "normal" lung function is indicated by the pattern classifier returning "Normal" rather than by the severity grade itself. Pass only percent-predicted values from patients with an identified impairment.

Usage

```
pft_severity_2005(pctpred)
```

Arguments

`pctpred`	Numeric vector of FEV1 percent predicted values (e.g. the `fev1_pctpred` column from `pft_spirometry()` times nothing – it is already a percent).

Value

Character vector the same length as `pctpred` with values `"mild"`, `"moderate"`, `"moderately severe"`, `"severe"`, `"very severe"`, or `NA`.

References

Pellegrino R, Viegi G, Brusasco V, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005;26(5):948-968. doi:10.1183/09031936.05.00035205. Severity bands taken from Table 4.

See Also

`pft_severity()` for the current Stanojevic 2022 z-score-based grading. `pft_classify()` with `standard = "2005"` for the matching 2005-era pattern classifier.

Examples

```
pft_severity_2005(c(85, 65, 55, 40, 30))
# -> "mild" "moderate" "moderately severe" "severe" "very severe"
```

`pft_spirometry` *Compute spirometry reference values for given demographics*

Description

`pft_spirometry()` computes ATS-compliant upper and lower normal limits for common spirometry measures including FEV1, FVC, FEV1/FVC, FEF2575, and FEF75.

Usage

```
pft_spirometry(
  data,
  year = 2022,
  sex = sex,
  age = age,
  height = height,
  race = race
)
```

Arguments

data
: A data frame containing columns for sex ("M","F"), race ("AfrAm","NEAsia","SEAsia","Other/mixed", "Caucasian"), age (in years, in the range 3-95 for FEV1 / FVC / FEV1/FVC and 3-90 for FEF25-75 / FEF75 per the GLI spline tables), and height (in centimeters). Rows with NA in sex, age, or height (or, for GLI 2012, in race) are returned with NA reference values. Race is ignored when year = 2022 (GLI Global equations are race-neutral).

  If data also contains any of fev1_measured, fvc_measured, fev1fvc_measured, fef2575_measured, fef75_measured, the corresponding measured value is used to compute a z-score and percent-predicted for that measure (see Value).

year
: The year of GLI published equations. Valid options are 2012 (multi-ethnic, requires a race column) and 2022 (race-neutral "GLI Global"; the race column, if present, is ignored). Defaults to 2022, the current ERS/ATS recommendation.

sex, age, height, race
: Column references. By default pft_spirometry() reads from sex, age, height, and (for GLI 2012) race. If your data frame names them differently, override via a bare name (sex = Sex), a string (sex = "Sex"), or an rlang injection (sex = !!my_var). The user's original column names are preserved in the output.

Value

The original data frame with extra columns appended for each measure. Every output column carries the GLI year as a suffix so a single result frame can hold multiple equation outputs side-by-side (fev1_pred_2012, fev1_pred_2022, ...).

- <measure>_pred_<year>: predicted (median) value.
- <measure>_lln_<year>: lower limit of normal (5th percentile).
- <measure>_uln_<year>: upper limit of normal (95th percentile). If a <measure>_measured column was supplied in data, two additional columns are emitted:
- <measure>_zscore_<year>: LMS z-score ((measured/M)^L - 1) / (L*S).
- <measure>_pctpred_<year>: percent predicted (measured / pred) * 100.

References

Quanjer PH, Stanojevic S, Cole TJ, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations. Eur Respir J. 2012;40(6):1324-1343. doi:10.1183/09031936.00080312.

Bowerman C, Bhakta NR, Brazzale D, et al. A race-neutral approach to the interpretation of lung function measurements. Am J Respir Crit Care Med. 2023;207(6):768-774. doi:10.1164/rccm.202205-0963OC.

See Also

`pft_volumes()` and `pft_diffusion()` for the analogous reference-value functions for lung volumes and diffusion capacity. `pft_classify()` consumes the LLN columns produced here to assign ATS interpretive patterns. `pft_interpret()` is the one-call wrapper that combines spirometry, volumes, diffusion, and all downstream interpretation primitives.

Examples

```
data <- data.frame(sex=c("M","F"),
                   age=c(30.1,5.1),
                   height=c(178,50),
                   race=c("SEAsia","NEAsia"))
pft_spirometry(data)
```

---

pft_volume_subpattern *Classify lung-volume sub-pattern per Stanojevic 2022 Figure 10*

Description

Differentiates the six lung-volume sub-patterns described in the 2022 ERS/ATS interpretive standard: **Normal lung volumes**, **Large lungs**, **Hyperinflation**, **Simple restriction**, **Complex restriction**, and **Mixed disorder**. These are the patterns that `pft_classify()` collapses into "Restricted", "Mixed", and "Obstructed" / "Normal" – this function recovers the finer-grained labels when lung-volume ratios (FRC/TLC and / or RV/TLC) are available.

Typically called via `pft_interpret()` as part of the one-call workflow; exported for callers who want to apply the sub-pattern classifier to pre-computed columns directly.

Usage

```
pft_volume_subpattern(
  data,
  year = 2022,
  tlc = tlc,
  tlc_lln = tlc_lln,
  tlc_uln = tlc_uln,
  fev1fvc = fev1fvc,
  fev1fvc_lln = NULL,
  rv_tlc = rv_tlc,
  rv_tlc_uln = rv_tlc_uln,
  frc_tlc = NULL,
  frc_tlc_uln = NULL
)
```

Arguments

`data`
: A data frame containing at minimum:

  - `tlc`, `tlc_lln`, `tlc_uln`
  - `fev1fvc`, `fev1fvc_lln`
  - `rv_tlc`, `rv_tlc_uln`

  Optional columns to refine the elevated-volumes branch:

  - `frc_tlc`, `frc_tlc_uln`

`year`
: GLI year suffix used when looking up the spirometry FEV1/FVC LLN column. Defaults to `2022`. Set to match the `year` argument used in the upstream `pft_spirometry()` / `pft_interpret()` call. The TLC and RV/TLC columns (volumes reference) are unsuffixed and are not affected by `year`.

`tlc`, `tlc_lln`, `tlc_uln`, `fev1fvc`, `fev1fvc_lln`, `rv_tlc`, `rv_tlc_uln`
: Column references for the seven required inputs. Defaults are the canonical names (`fev1fvc_lln` carries the `_<year>` suffix); override with a bare name, a string, or `!!var` (see "Column-name overrides" below).

`frc_tlc`, `frc_tlc_uln`
: Column references for the optional FRC/TLC pair. Default `NULL` means: auto-pickup if `frc_tlc` and `frc_tlc_uln` exist in `data`, otherwise skip the FRC branch and classify on RV/TLC alone.

Details

Implements the decision tree in Figure 10 of Stanojevic et al. ERJ 2022 (p. 21) verbatim:

```
TLC < 5th percentile (LLN)?
  YES -> Restriction:
    FRC/TLC OR RV/TLC > 95th percentile (ULN)?
      YES:
        FEV1/FVC < 5th percentile?
          YES -> "Mixed disorder"
          NO  -> "Complex restriction"
      NO    -> "Simple restriction"
  NO:
    TLC > 95th percentile?
      YES (possible hyperinflation):
        FRC/TLC OR RV/TLC > 95th percentile?
          YES -> "Hyperinflation"
          NO  -> "Large lungs"
      NO:
        FRC/TLC OR RV/TLC > 95th percentile?
          YES -> "Hyperinflation"
          NO  -> "Normal lung volumes"
```

RV/TLC reference ranges are produced by `pft_volumes()` (per Hall 2021 Table 3 row for RV/TLC). FRC/TLC is not fitted in the Hall 2021 standard; if the caller has FRC/TLC and its ULN available, supply them as columns `frc_tlc` / `frc_tlc_uln` to refine the OR-condition. When absent (the typical case), only RV/TLC is consulted – the function degrades gracefully.

Value

The input data with a new `volume_subpattern` character column appended. Values are one of `"Normal lung volumes"`, `"Large lungs"`, `"Hyperinflation"`, `"Simple restriction"`, `"Complex restriction"`, `"Mixed disorder"`, or `NA_character_` if any required column is `NA` for that row.

Column-name overrides

Each column-reference argument accepts three forms:

- a **bare column name** – `tlc = my_tlc`
- a **string** – `tlc = "my_tlc"`
- an **injected value** – `tlc = !!my_var` where `my_var <- "my_tlc"`

Defaults are the canonical pft column names, so callers whose data already follows the convention pass no extra arguments. The optional FRC/TLC pair (`frc_tlc`, `frc_tlc_uln`) defaults to `NULL` to enable canonical-name auto-pickup; pass explicit column references to override.

References

Stanojevic S, Kaminsky DA, Miller MR, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. Eur Respir J. 2022;60(1):2101499. doi:10.1183/13993003.01499-2021. Lung-volume sub-patterns defined in Figure 10 (p. 21) and Table 7 (p. 22).

See Also

`pft_classify()` for the five-band airflow / restriction classification; `pft_volumes()` to obtain `rv_tlc` / `rv_tlc_uln` per Hall 2021; `pft_interpret()` composes both classifications when the input columns are present.

Examples

```
# Mixed disorder: TLC < LLN, RV/TLC > ULN, FEV1/FVC < LLN.
data.frame(
  tlc = 4.0, tlc_lln = 5.0, tlc_uln = 7.0,
  fev1fvc = 0.55, fev1fvc_lln_2022 = 0.70,
  rv_tlc = 0.55, rv_tlc_uln = 0.45
) |> pft_volume_subpattern()

# Simple restriction: TLC < LLN, both ratios normal.
data.frame(
  tlc = 4.0, tlc_lln = 5.0, tlc_uln = 7.0,
  fev1fvc = 0.80, fev1fvc_lln_2022 = 0.70,
  rv_tlc = 0.30, rv_tlc_uln = 0.45
) |> pft_volume_subpattern()
```

pft_volumes *Compute lung volume reference values for given demographics*

Description

pft_volumes() computes ATS-compliant upper and lower normal limits for lung volume measures including FRC, TLC, RV, ERV, IC, and VC.

Usage

```
pft_volumes(data, sex = sex, age = age, height = height)
```

Arguments

data	A data frame containing columns for sex ("M","F"), age (in years, in the range 5-80 per the GLI 2021 spline tables) and height (in centimeters). If data also contains any of frc_measured, tlc_measured, rv_measured, rv_tlc_measured, erv_measured, ic_measured, vc_measured, the corresponding measured value is used to compute a z-score and percent-predicted (see Value).
sex, age, height	Column references. By default pft_volumes() reads from sex, age, and height. Override via a bare name (sex = Sex), a string (sex = "Sex"), or an rlang injection (sex = !!my_var). The user's original column names are preserved in the output.

Value

The original data frame with extra columns appended for each measure:

- <measure>_pred: predicted (median) value.
- <measure>_lln: lower limit of normal (5th percentile).
- <measure>_uln: upper limit of normal (95th percentile). If a <measure>_measured column was supplied in data, two additional columns are emitted:
- <measure>_zscore: LMS z-score ((measured/M)^L - 1) / (L*S).
- <measure>_pctpred: percent predicted (measured / pred) * 100.

References

Hall GL, Filipow N, Ruppel G, et al. Official ERS technical standard: Global Lung Function Initiative reference values for static lung volumes in individuals of European ancestry. Eur Respir J. 2021;57(3):2000289. doi:10.1183/13993003.002892020.

See Also

pft_spirometry() and pft_diffusion() for the analogous reference-value functions. pft_classify() uses TLC and its LLN (produced by this function) to identify restrictive impairments. pft_interpret() composes all three reference functions in one call.

Examples

```
data <- data.frame(sex=c("M","F"),
                   age=c(30,5.1),
                   height=c(178,50))
pft_volumes(data)
```

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